THE CASE OF THE

METHODIST CHAPEL FAILURE

Human errors caused the collapse of this beautiful $83,000 chapel. These errors were made by the architect, engineer, general contractor and sub-contractor, all of whom suffered financial loss as a result. Study of this case is especially appropriate for courses in civil engineering structural analysis and design.

All names are fictitious

 Prepared by Professor Paul H. Sanders, Georgia Institute of Technology. Published with the support of the National Science Foundation.

THE CASE OF THE METHODIST CHAPEL FAILURE

The shrill ring of the telephone stirred Joe Church from an uneasy slumber. He groped unsteadily for the phone, found it and answered, knowing instinctively who was on the other end and what the message was.

"Joe," came the weary voice over the receiver. "It's happened."

"When, Charlie?" Joe asked.

"About five minutes ago. It was nine o'clock. We heard a rumble - - and boom! The whole thing fell in."

There was a long heavy silence. Then Joe asked if anyone were hurt.

"No," Charlie replied. "When I called you earlier, we figured this would happen so we evacuated everyone working on the building. What now?"

"There's nothing you or I can accomplish tonight," Joe said. "Why don't you tell everyone to go on home, and we'll decide what to do with this mess tomorrow morning."

Dejectedly, Joe hung up the telephone, then sank into the worn leather chair next to the desk. So, it had finally happened, he thought to himself. The Methodist Center Chapel on Piedmont and Forrest Avenues in Atlanta had come to an unglorious end. It had collapsed, and no one knew why or where to place the blame.

Only one thing was certain. On this muggy night in August, 1966, the nearly completed edifice had in one swift stroke fallen into complete ruin.

Was it his fault? He sat very still for what seemed like hours, then went to his file to pull out a large over-stuffed manila folder complete with specifications, plans and other materials. He was determined to find out what had happened, for never in the twenty years that he had worked as a structural engineer had a building of his collapsed.

The 44-year-old bent his graying head over the drawings and was still absorbed in deep study when the first light of dawn came creeping through the study window. The sun was high in the sky when he finally ceased his figuring, still completely in the dark as to the cause of what he knew was a costly and potentially damaging event for many people.

* * *

Three days after the collapse, Joe found himself standing before what remained of the Methodist Chapel. He felt the heat of the hot summer sun which beat down on massive white concrete obelisks lying scattered in the vacant lot. Twisted pieces of brown-colored steel lay interspersed among the broken concrete, and represented what had once almost been a beautiful chapel.

"What a mess," Joe murmured to himself. He nervously jumped when a deep voice broke his reverie to agree.

Joe broke his eyes away from the spectacle before him long enough to look upon a young man in shirt sleeves with a camera dangling from one shoulder.

"I'm George Petrie," the man said, "with Peachtree Engineering."

"Peachtree Engineering." Joe repeated absent-mindedly, his thoughts still upon the rubble heap. A second later his eyes brightened, his interest renewed. "That's the company that investigates accidents, right?"

Petrie answered to the affirmative and said he was a civil engineer who had been hired to investigate the Methodist Chapel failure. The company, he explained, serviced mostly insurance companies; in this case, the client was Magnolia Casualty Company. The Magnolia Company specialized in various types of commercial insurance and had issued a liability policy to Zenith Erectors, the erection sub-contractor for the Methodist Chapel.

"Well, I guess we'll be talking at length," Joe said after explaining who he was and why he was there. "I'll tell you, this whole matter has just stumped me."

Petrie nodded and continued his inspection of the structural members, that, three days before, had formed the skeleton of the Methodist Chapel.

"You don't have any idea of what caused this?" Petrie asked.

Joe heaved a sigh, threw up his hands in bewilderment and began pointing out some of the details of the building to Petrie.

"This was to be the 40-foot diameter chapel," Joe said. "The circular construction was situated on the top deck of an underground parking facility. There were to be 12 identical equally-spaced precast concrete exterior columns supporting the roof, which was composed of a dozen identical precast concrete elements and a circular center compression ring member which also supported the steeple. A tension ring of steel connected the tops of the columns to provide the necessary horizontal reaction for the equilibrium of the 12 roof elements."

"As this was designed," Joe continued, "after the compression ring was connected by welding to the roof elements, the space between it and the elements was grouted as were the spaces between the roof elements."

The two men talked further with Petrie listening attentively to every detail explained by the structural engineer. After a long conversation, Petrie returned to his office.

* * *

"George, this is a bad one," said Bill Scruggs, George's boss and the owner of Peachtree Engineering. "Magnolia Casualty may have to pay the entire $80,000 cost of rebuilding the chapel. It looks like Zenith Erectors did a poor job of welding. What did you find out there?"

The young civil engineer told his employer of his chance encounter with the structural engineer of the chapel, repeated the information he had received and observed, "In looking over the job it appeared that nearly all the tension ring welds had fractured. No metal fractures occurred at places other than welded joints. The welds were uneven and sloppy and the shop paint hadn't even been removed from the vicinity of the welds. I think the welds broke first, then the structure collapsed."

Scruggs nodded, then asked Petrie to obtain all pertinent construction drawings, documents and specifications.

"Try to find out what kind of weld was called for to begin with," Scruggs instructed. "The specifications should have references to painting of welded members."

Petrie was nearly out of the door when Scruggs stopped him and added another item to the list. "Just in case the design engineer was in error, run a stress analysis on the tension ring welds."

Several weeks later, Petrie returned for another conference with Scruggs loaded down with documents, specifications, construction drawings and seven drawings of his own (Figures 1 through 7) giving the details of the structure of the chapel. He had used the drawings to run a stress analysis and had come up with some startling revelations.

"Bill, I've found quite a few facts which may put the blame for this failure on the architect, structural engineer, general contractor and steel fabricator and save our client a lot of money. But there's something strange involved in this whole thing that I haven't quite been able to put my finger on," Petrie said, perplexed.

"The stress analysis showed the maximum stress at the welded joints on the tension ring to be somewhat less than the 21,600 psi (for E60 electrodes and A-36 steel) allowed in the AISC specifications."[1]

"Did you remember to include the live load in your stress analysis?" Scruggs queried.

Petrie nodded repeating that the pertinent Atlanta Building Code of 1961 calls for a live load of 25 psf acting normal to the horizontal plane.

Scruggs shook his head. He thought for several seconds, then questioned Petrie again. "How about considering that 21,600 psi is the maximum allowable stress only for full penetration welds?" he asked.

Petrie grimaced and shrugged his shoulders. "That's the funny part of this whole business, Bill. Would you believe that three different weld symbols were used on three different drawings to depict the connection between segments of the tension ring?"

He pulled out from his stack of papers the eighth (Figure 8) in his series of drawings. It was an excerpt from the architect's drawing which showed the symbol for "bevel groove weld, all around".

Figure 9 was quite a different story. This was from the steel fabricator's drawing marked "for approval only" showing the symbol for "flash or upset resistance weld, convex contour, field weld".

---

[1] Section 1.5.3.2 Specification for this Design, Fabrication and Erection of Structural Steel for Buildings (Adopted April 17, 1963).

Figure 10 showed an excerpt of the steel fabricator's drawing marked "field use." On that drawing, the weld symbol of Figure 9 was modified to "all around."

"I've never heard of flash or resistance welding being used in a case like this, Petrie mused. "I always thought that flash or resistance welding was used to put together automobiles and refrigerators."

"Wait a minute,' Scruggs interrupted. "I seem to recall that years ago that symbol used by the steel fabricator stood for 'butt weld.' Why don't you check some old welding specifications?"

* * *

A week later, George Petrie had the answer. He rushed into Scruggs office with a triumphant grin and handed him a portfolio.

"Well?" Scruggs asked, "what did you find out?"

"That you can't trust anyone over 35," Petrie replied with a chuckle. "This is really incredible."

"What are you talking about?" Scruggs asked, perplexed at his young associate's good humor.

"You were right," Petrie said. "In 1946 those weld symbols on the steel fabricator's drawings meant 'butt weld'! So now I think I've got an explanation for the weld symbol change."

He continued that Joe Church, the structural engineer, was quite correct when he called for the welding to be done according to the symbol shown on Figure 8, the architect's drawing.

"But some old timer at the steel fabricator's shop thought he saw a way to save a hundred bucks or so and changed this symbol to one which didn't require hand grinding of the bevel for the groove weld. Yet it still specified a full penetration weld," Petrie explained.

"The architect and engineer approved the steel fabricator's drawing not noticing the weld symbol change. And the welder employed by the erection sub-contractor, Zenith, probably paid little or no attention to the weld symbol and tried to make the best possible weld."

Petrie did add however, that the Zenith crew could take some of the blame.

"They were probably in too much of a hurry to remove the shop paint from the weld area," the young civil engineer asserted as he showed his employer a regulation concerning painting in the Code for Welding in Building Construction.[2]

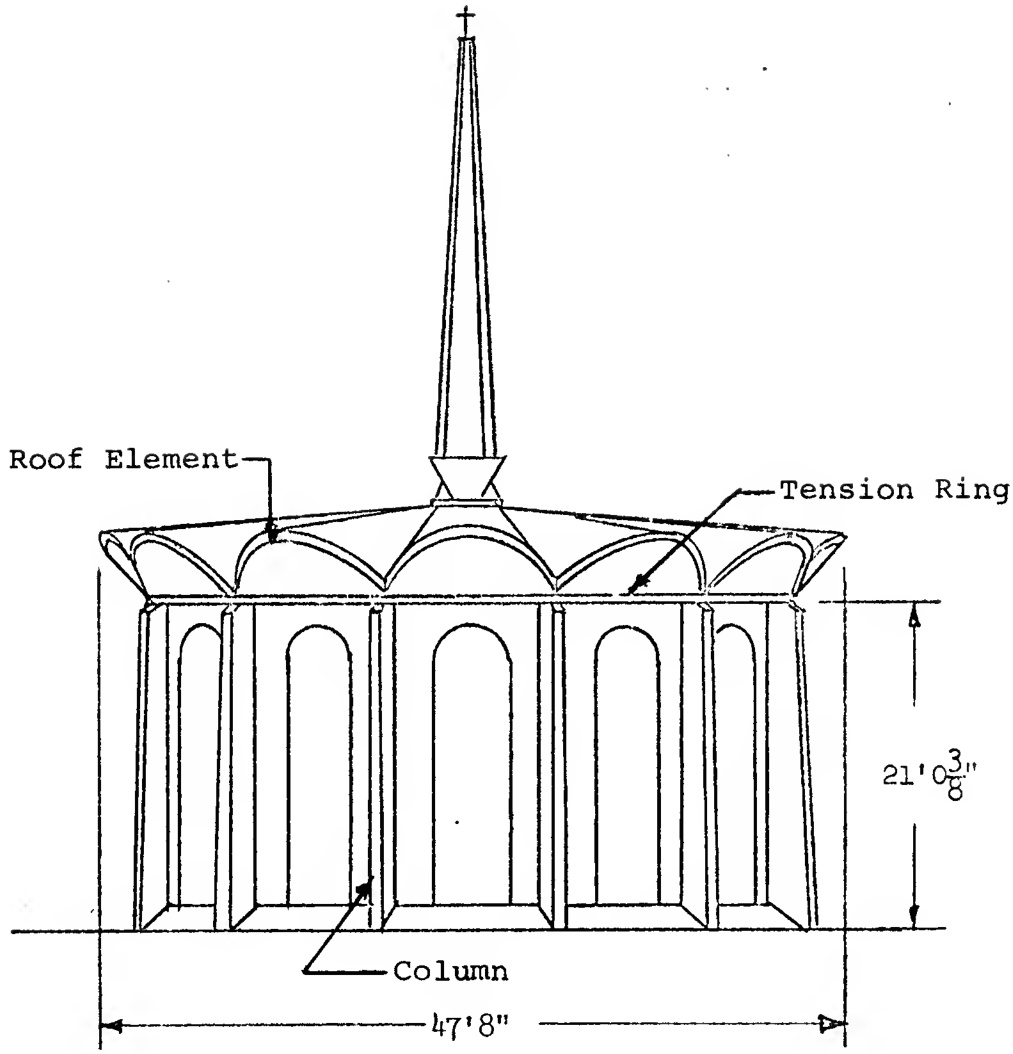
"Surfaces within two inches of any weld location shall be free from any paint or other material that would prevent proper welding or produce objectionable fumes while welding," the code section read.

"George," Scruggs said, "you've done a good job on this case. Go ahead and write the report to Magnolia Casualty. Their lawyer will need this information to settle this matter and I have a feeling that the settlement is going to turn into quite a complex issue."

Scruggs' prediction proved quite accurate. Settlement proved to be a three-year ordeal involving insurance companies, the structural engineer, the architect, contractor, steel fabricator and erection sub-contractor. The collapse of the chapel nearly resulted in a long and costly trial, but an out-of-court settlement in the end cost Joe Church and his colleagues $53,000, which was paid to the Kansas City Fire and Marine Insurance Company. The Kansas City Fire and Marine Insurance Company had paid $83,000 to the Methodist Center, Inc., under a "Builder's Risk" policy; they settled for $53,000 for a variety of reasons, suffering a $30,000 loss.

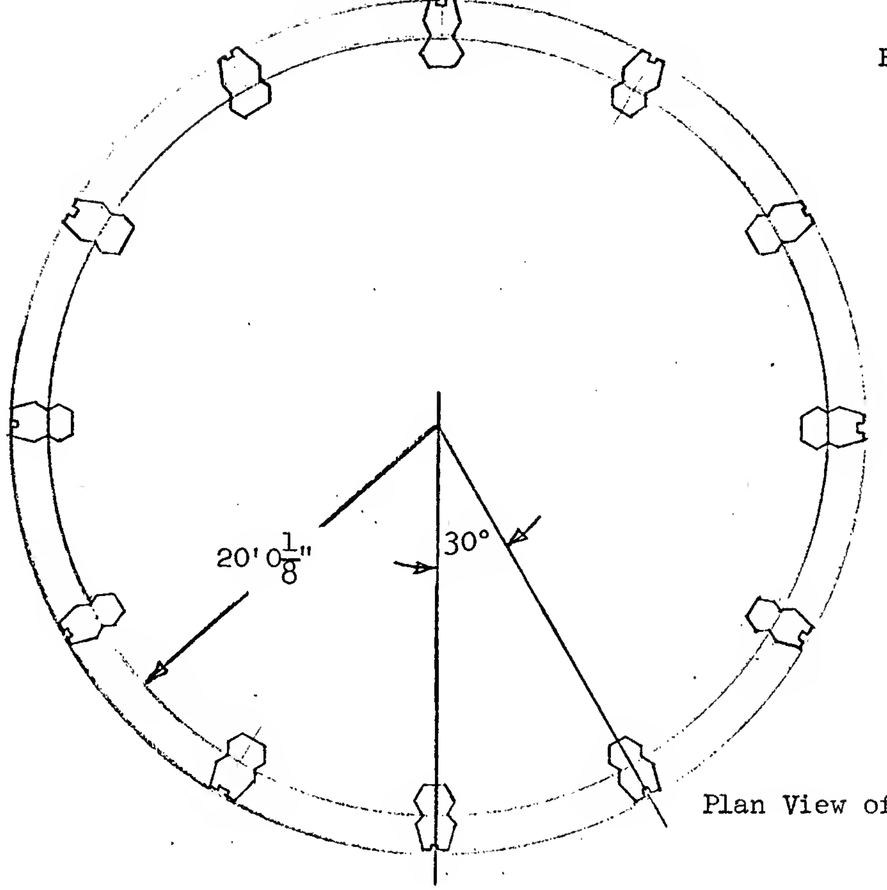
---

[2]AWS DI.0-66, adopted in 1966 by the American Welding Society.

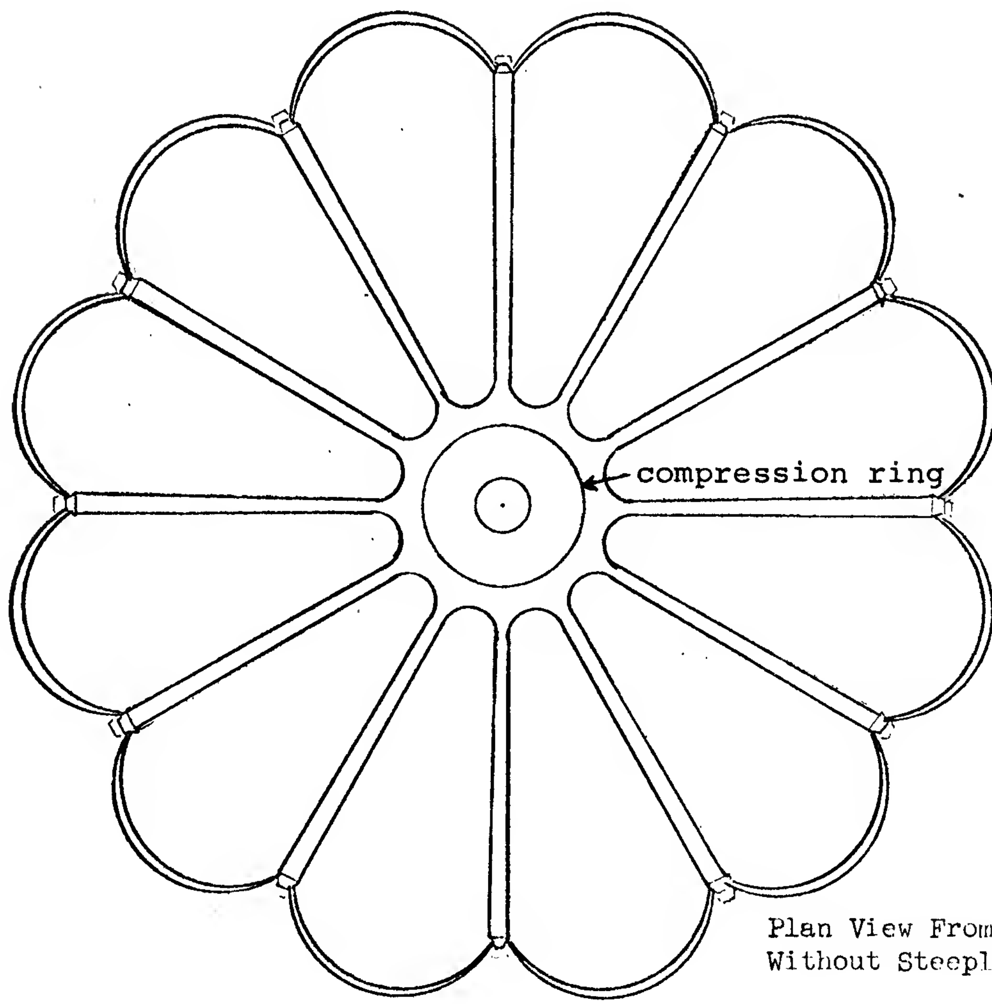


<u>Figure 1</u>

Methodist Center Chapel - Elevation

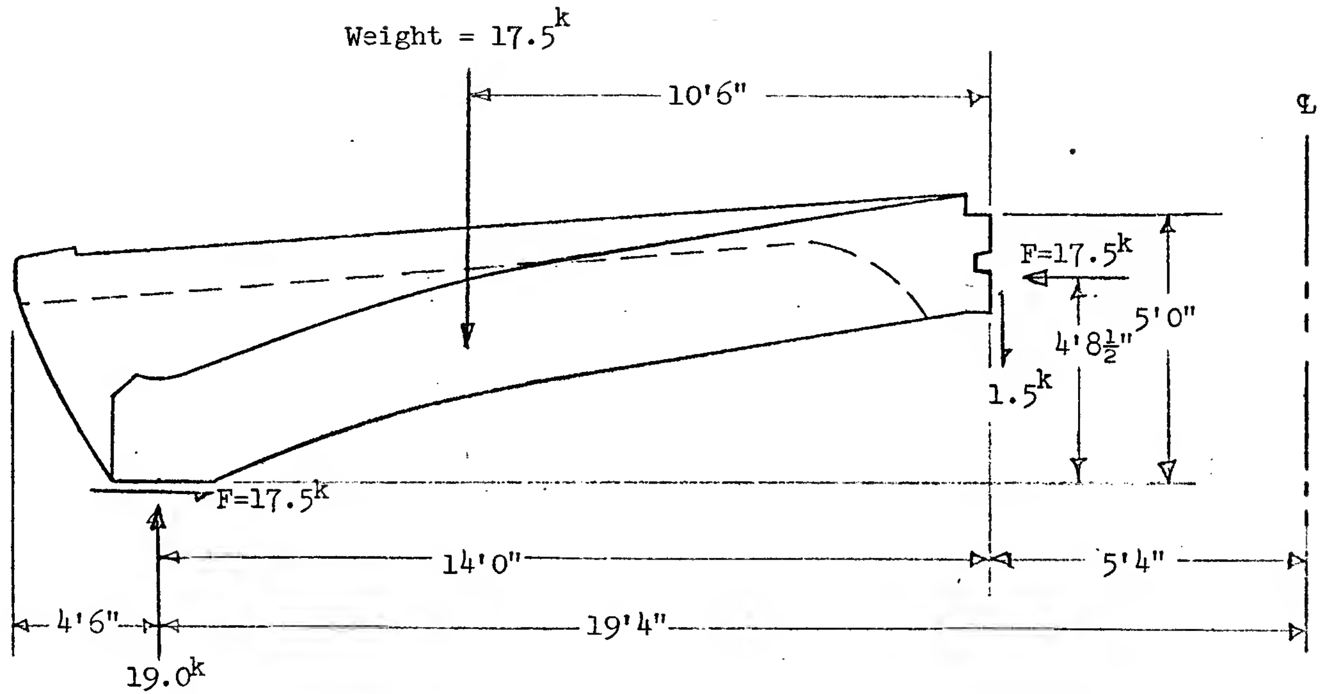


Plan View of Interior



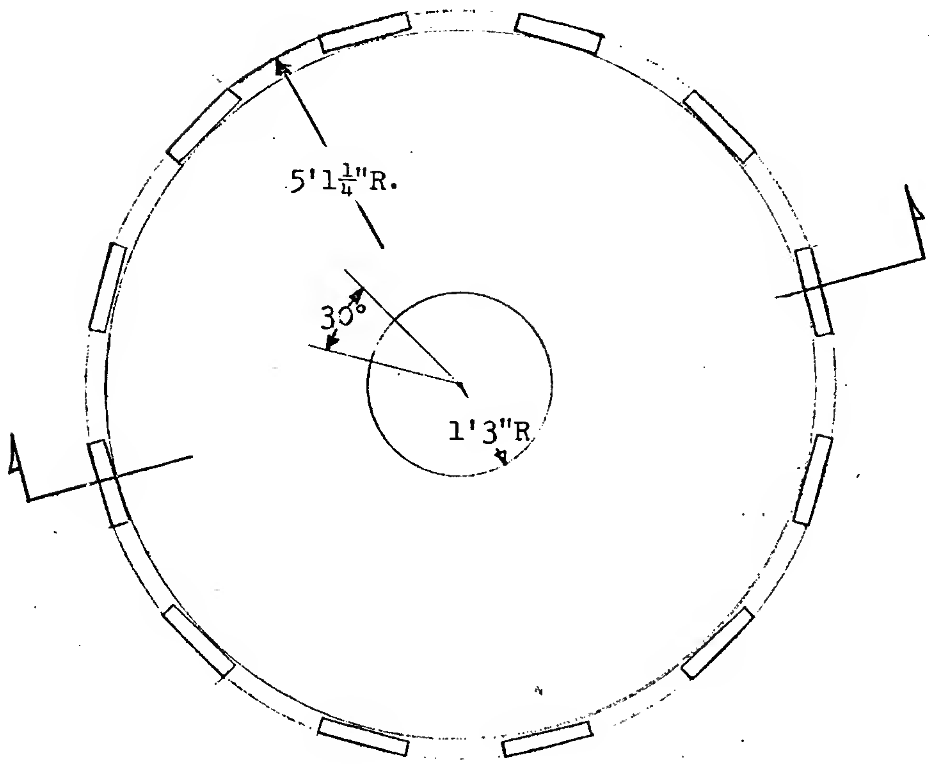
Plan View From Above
Without Steeple

<u>Figure 2</u>

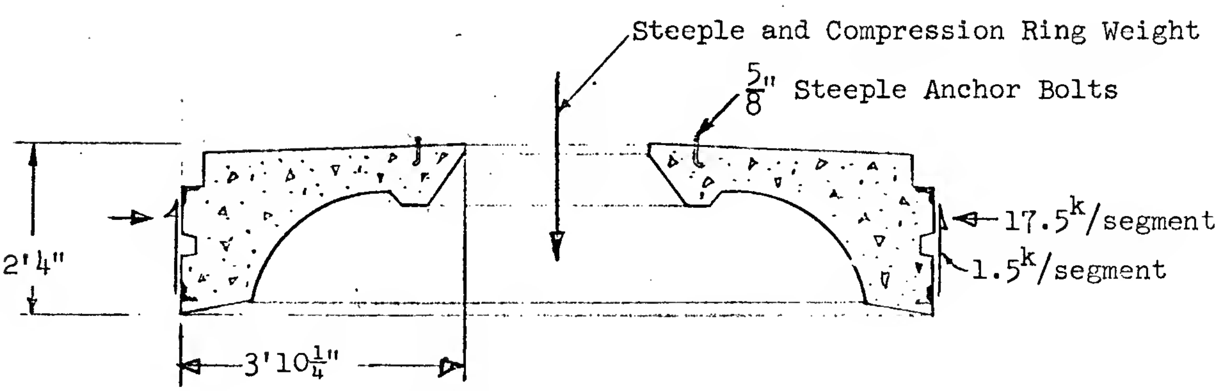


<u>Figure 3</u>

Dead Load Forces Acting on Typical Roof Segment



Compression Ring - Plan View



Compression Ring - Section

Figure 4a

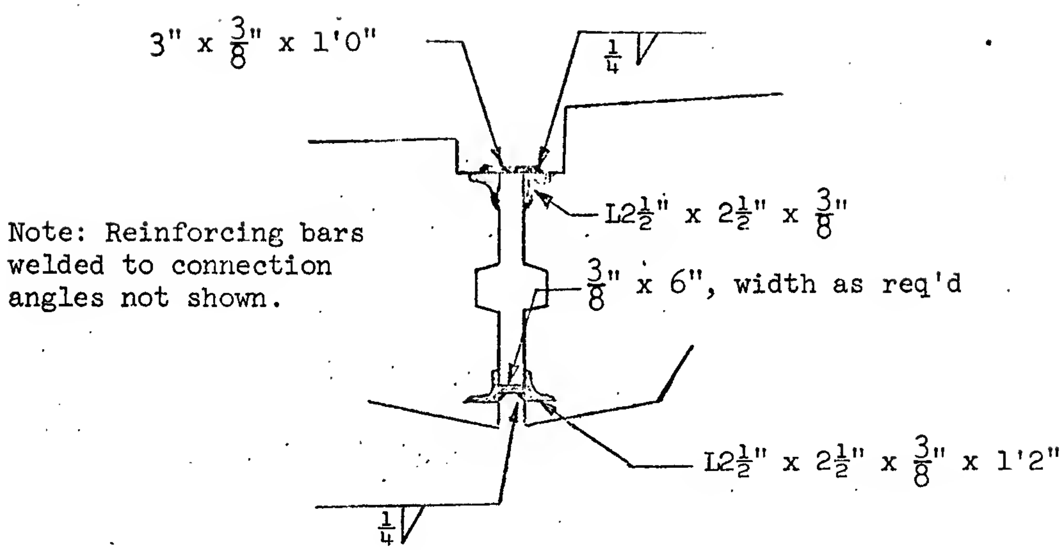
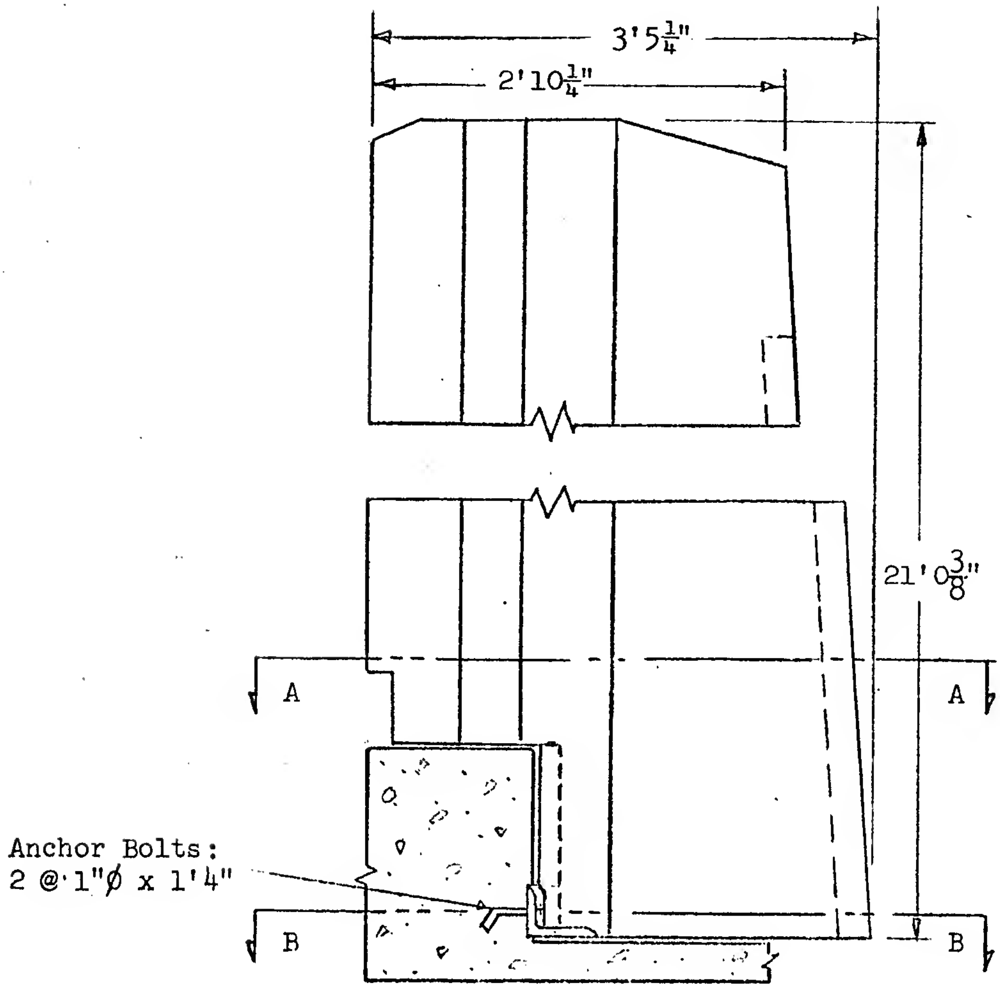
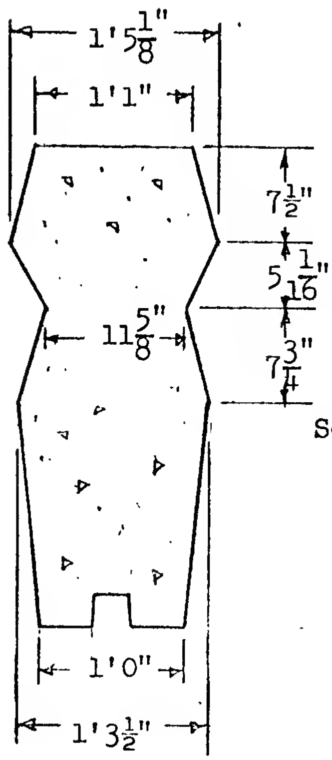


Figure 4b

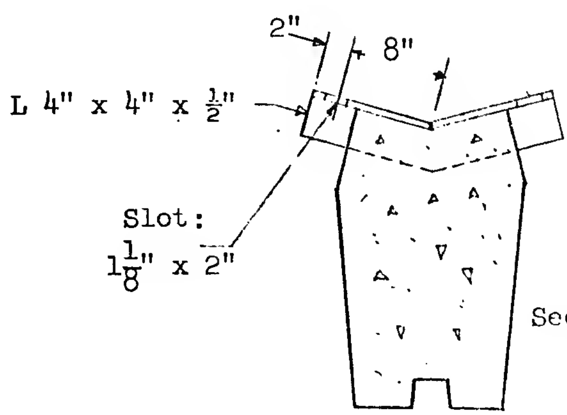
Compression Ring Connection Detail



Typical Precast Column

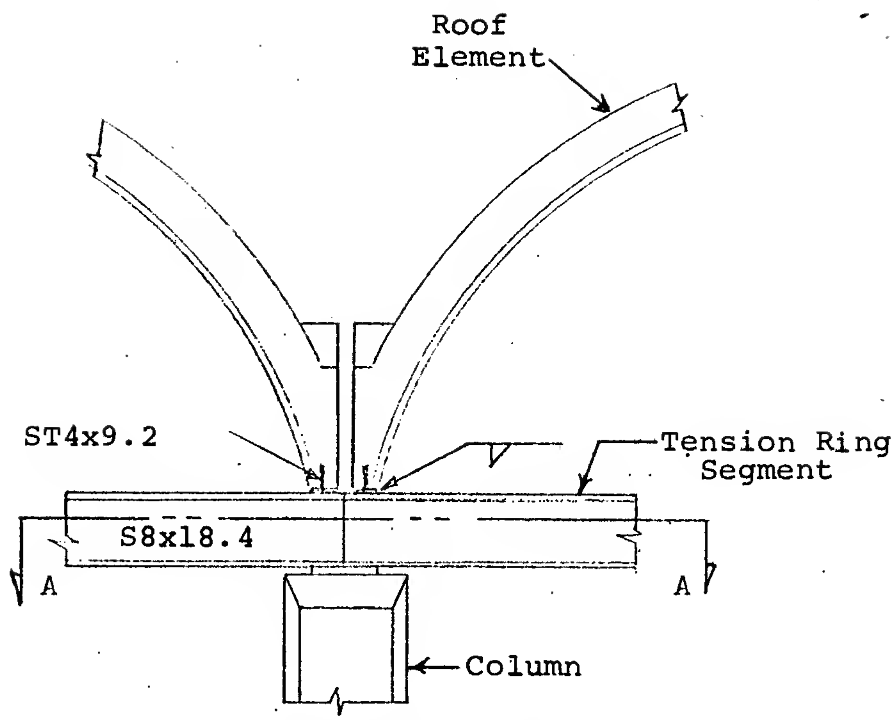


Section A-A



Section B-B

Figure 5



Typical Tension Ring Connection

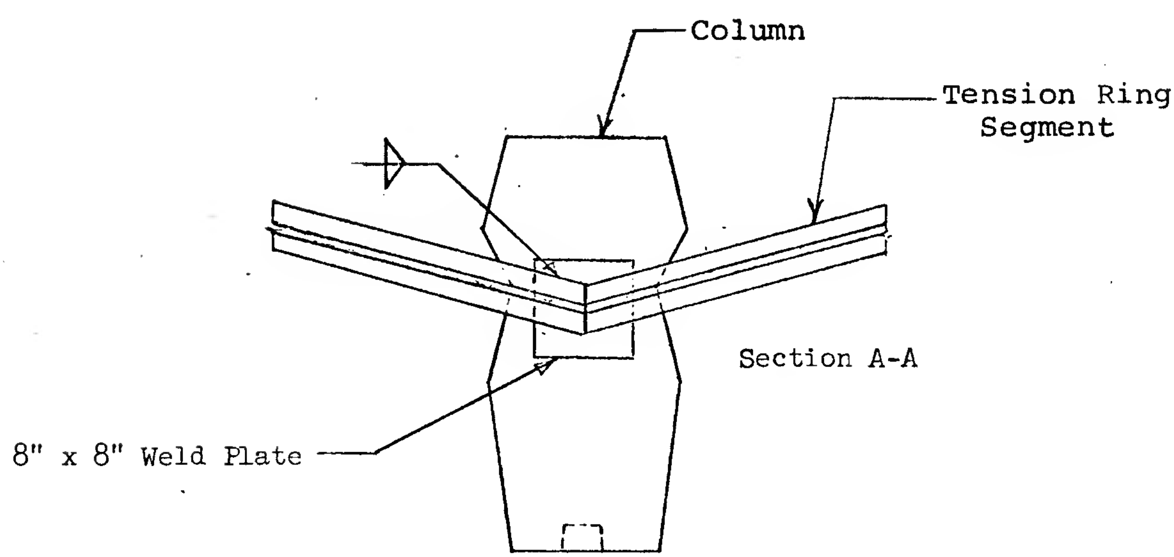
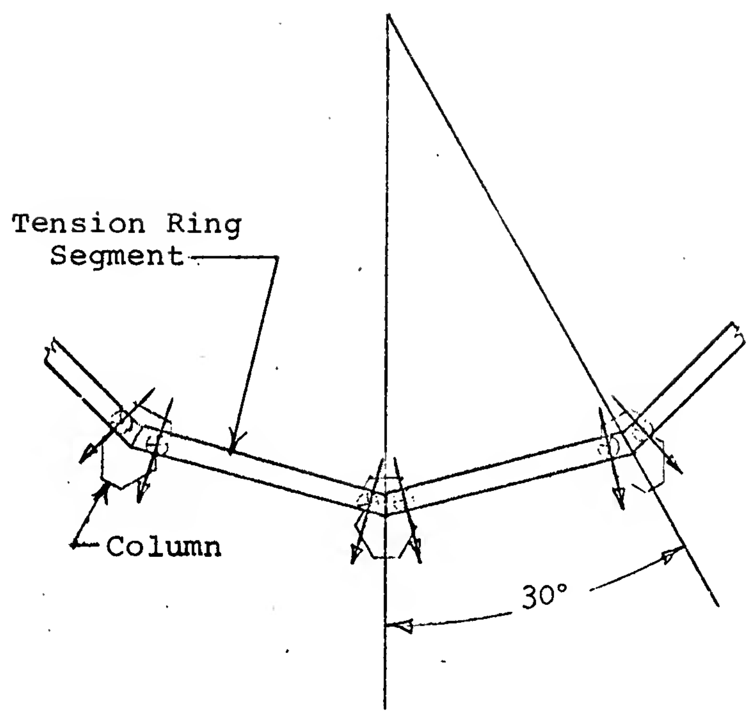


Figure 6



<u>Figure 7</u>

Plan View of Forces Acting on Top
Flange of Tension Ring

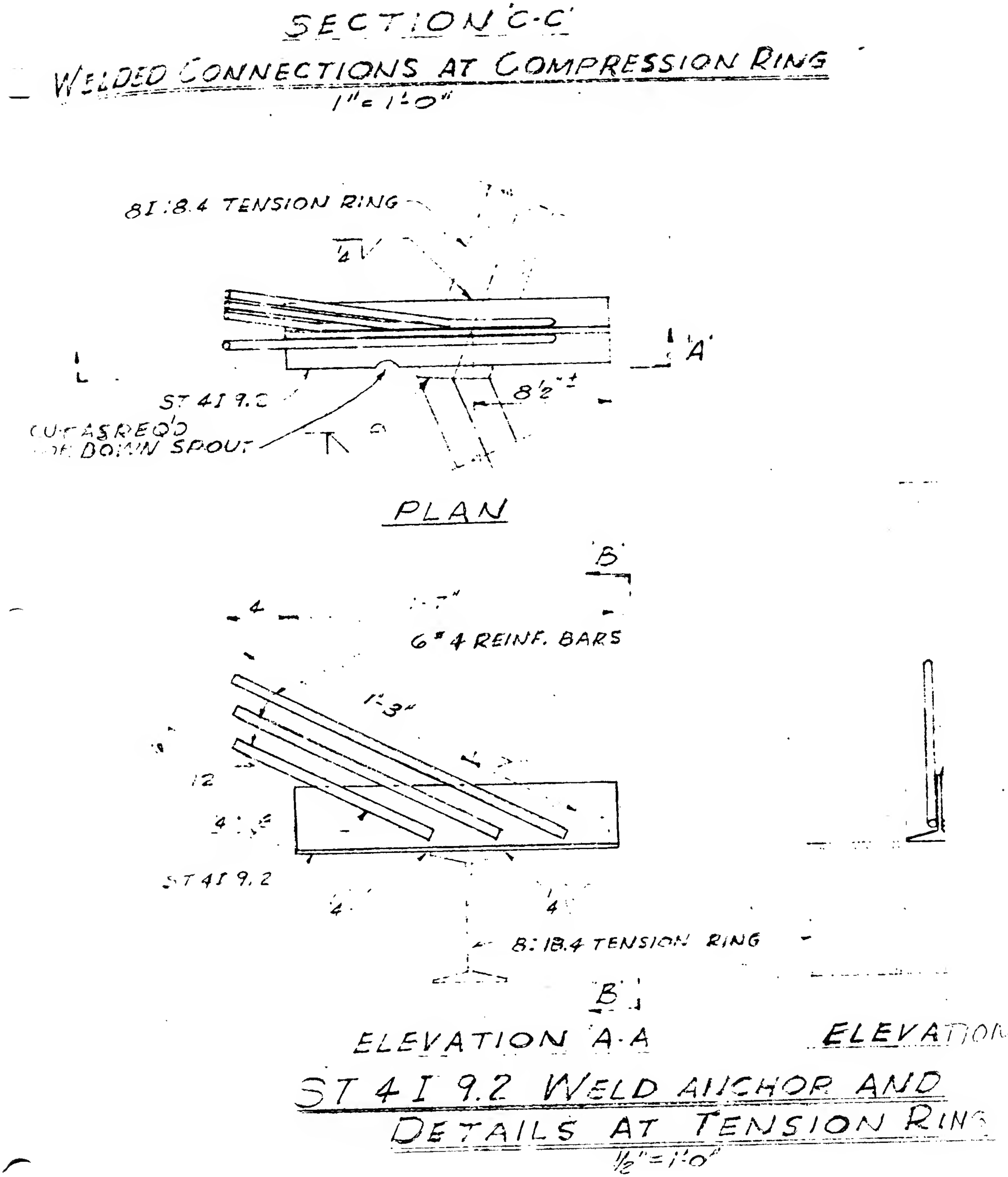


Figure 8

Architect's and Structural Engineer's Drawing

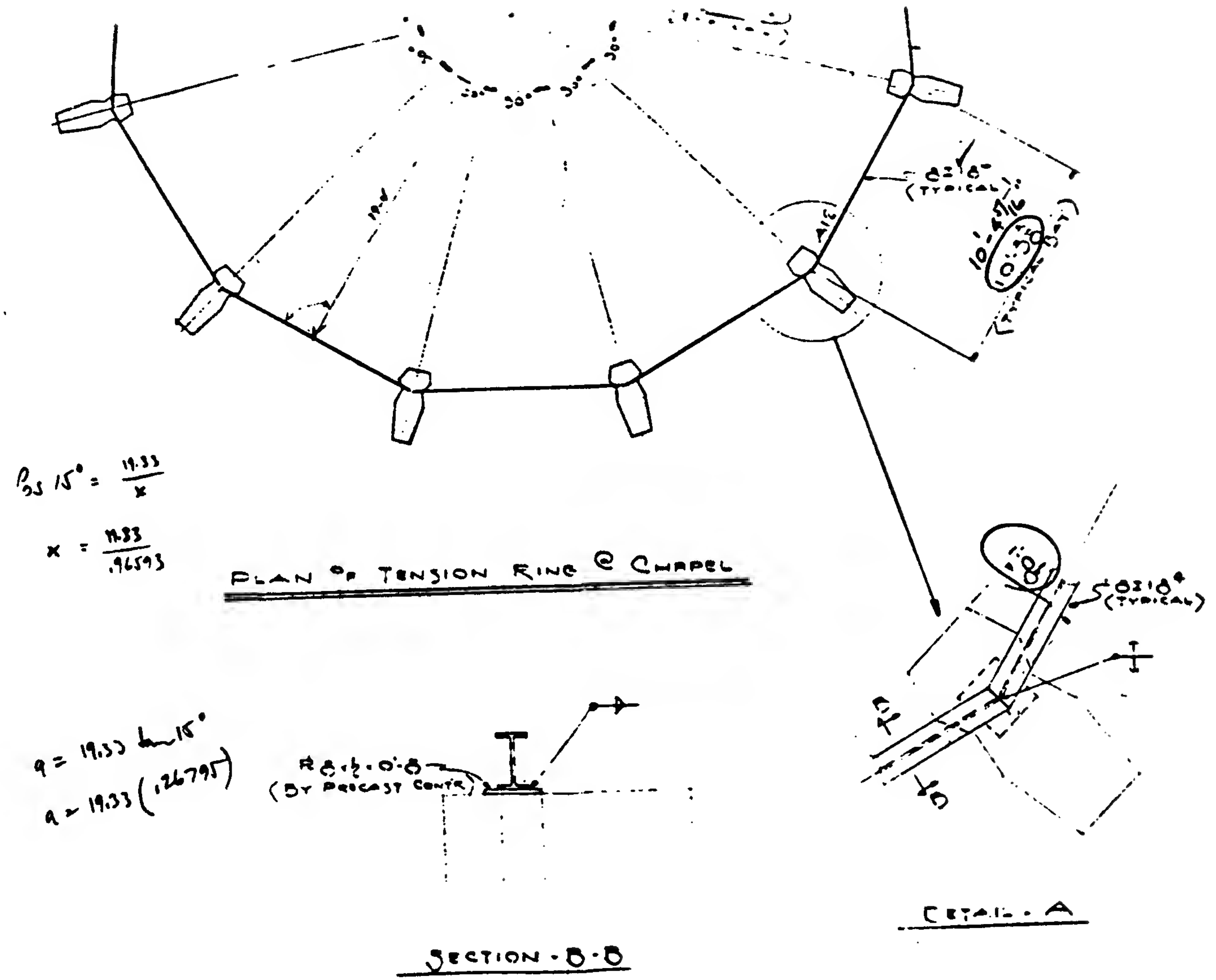


Figure 9

Marked "FOR APPROVAL ONLY" - Steel Fabricator

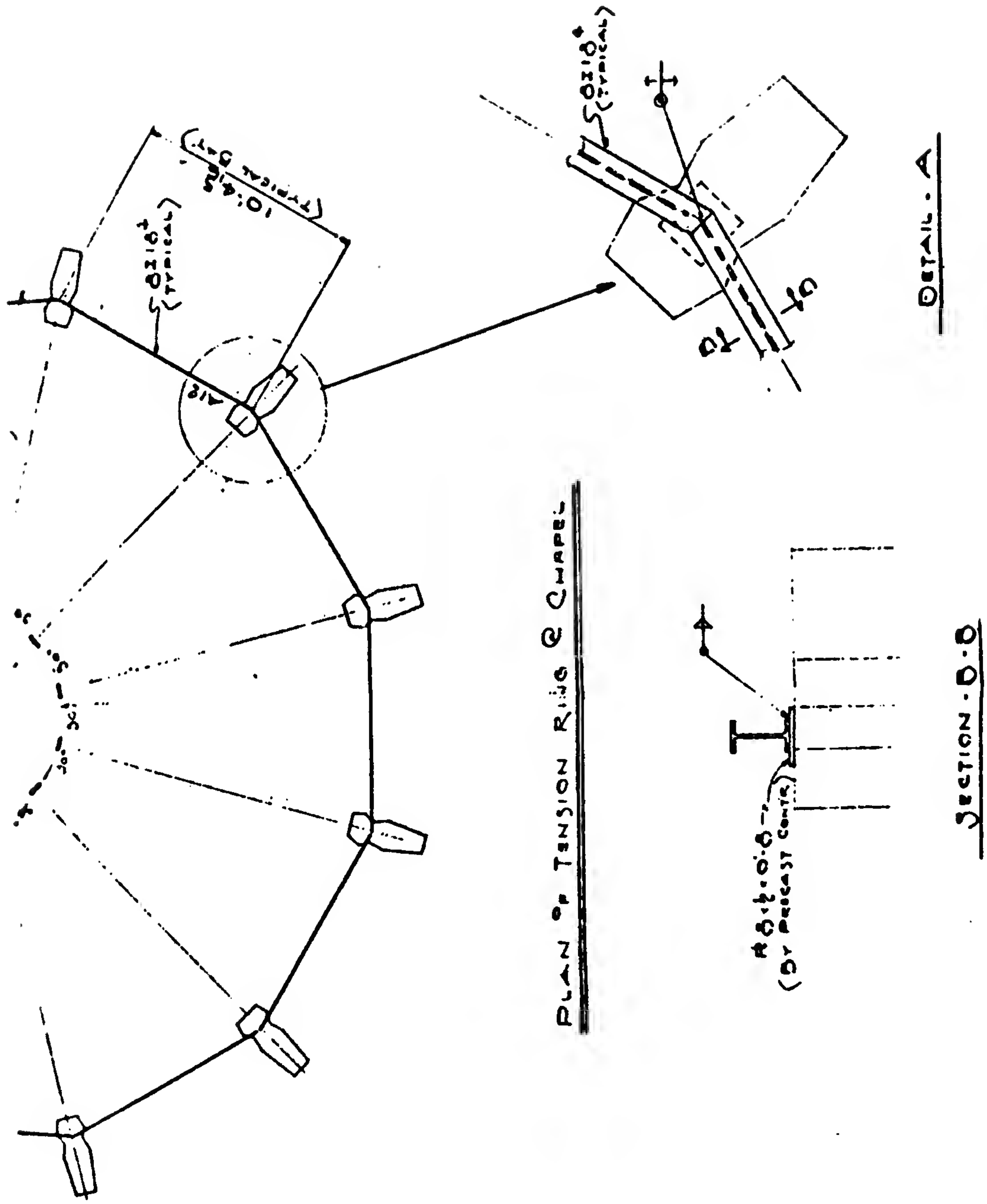


Figure 10

Marked "FIELD USE" - Steel Fabricator

INSTRUCTOR'S NOTE

The Case of the Methodist Chapel Failure

I. Introduction

This failure was caused by fracturing of the welds of the tension ring, which were later determined to have 30% average penetration, instead of 100% as intended by the structural engineer. As these welds parted, the top flanges of the tension ring moved outward, causing the roof segments to translate outward and rotate (clockwise on Figure 3). After some small displacement, the lower connections between roof segments and compression ring (Figure 4b) parted. At that point no moment resistance or arch action remained, and collapse ensued.

The author feels that one way in which this case can be used is to have the students run a stress analysis of the tension ring welds. The detailed calculations are given in Part II of this section. Another possible student exercise is a discussion of whose fault the failure was. This case was settled out of court; each of the parties involved paid the following:

Party	Amount	Percent
General Contractor	$ 7,500	14.2
Architect	2,500	4.7
Steel Fabricator	8,000	15.1
Erection Sub-contractor	23,000	43.3
Structural Engineer	12,000	22.7
	$ 53,000	100.0

Although the cost of rebuilding the Methodist Chapel was approximately $80,000, the owner's insurance company agreed to accept only $53,000 for an out-of-court settlement. The reasons for this difference are:

1. The payment is received immediately rather then perhaps two years later.

2. The cost of going to court to collect the $80,000 is a significant sum. The plaintiff's cost would be at least $10,000 for lawyer's fees, expert witness fees, etc. This cost would come out of any judgment received.

3. Between the time that an out-of-court settlement is offered by a defendant and the trial date, a defendant may be declared bankrupt; the plaintiff might then receive little or nothing for a settlement.

II. Stress Analysis of the Tension Ring

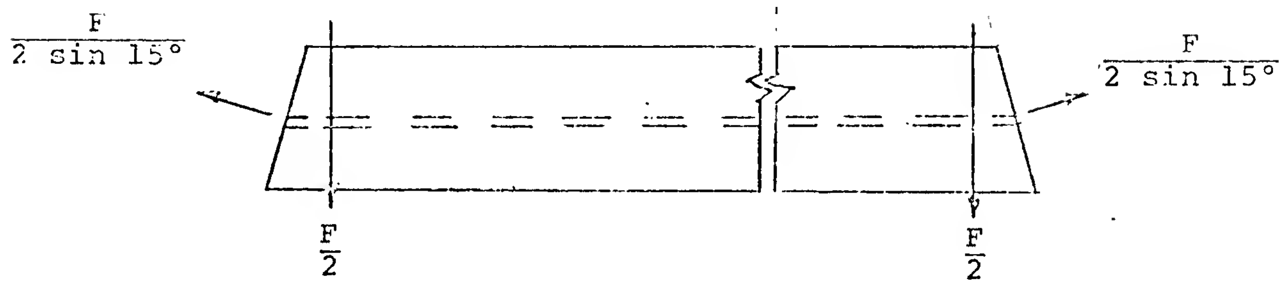


Figure 11

Force Detail on Tension Ring Segment

Since the web of the S8 x 18.4 is relatively thin (0.271 inches), it can be assumed that the force transmitted by it to the flange, in a horizontal direction perpendicular to the web, is negligible. Therefore, the normal force resisted by the weld in Figure 11 is calculated by (F from Figure 3)

$$\frac{F}{2 \sin 15°} = \frac{17.5^{k}}{(2)\ (.259)} = 33.6 \text{ kips}$$

Using the section properties of the welded face, the maximum dead load tension stress in the weld (at the top of the beam) is

$$33.6 \cos 15° \left(\frac{1}{5.34} + \frac{4}{14.4}\right) = 15.2 \text{ ksi}$$

The maximum live load tension stress, calculated similarly using a live load of 25 psf, is approximately 2.5 ksi. The total dead load plus live load tension stress is therefore 17.7 ksi. The maximum allowable stress for a weld which meets applicable codes and specifications is 21.6 ksi (for E60 electrodes and A-36 steel).

To the maximum dead load plus live load stress must be added the effects of wind, erection stresses, secondary effects due to warping of the beam cross-section, etc. The beam web was also subject to stresses due to the

Instructor's Note
(continued)

vertical compression force caused by the weight of the roof and sccondary stresses due to deflection of the top flange, which deformed the beam as depicted (exaggerated):